# TIME RESOLVED, 2-D HARD X-RAY IMAGING OF RELATIVISTIC ELECTRON-BEAM TARGET INTERACTIONS ON ETA-II*

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*Abstract*

Advanced radiographic applications require a constant source size less than 1 mm. To study the time history of a relativistic electron beam as it interacts with a bremsstrahlung converter, one of the diagnostics we use is a multi-frame time-resolved hard x-ray camera. We are performing experiments on the ETA-II accelerator at Lawrence Livermore National Laboratory to investigate details of the electron beam/converter interactions. The camera we are using contains 6 time-resolved images, each image is a 5 ns frame. By starting each successive frame 10 ns after the previous frame, we create a 6-frame movie from the hard x-rays produced from the interaction of the 50-ns electron beam pulse.

## 1 INTRODUCTION

Of the variety of diagnostic tools available to an experimenter, an image or picture representing salient features under investigation is a significant tool. At ETA-II, one of the diagnostics that provides reliable data is a 6-frame x-ray camera. This instrument, created at Sandia National Laboratories in 1985 by Dr. William A. Stygar, provides six time-resolved images and one time-integrated image of the hard x-rays produced by relativistic electron beam as it interacts with a bremsstrahlung converter.

## 2 THE CAMERA

To operate in a high, x-ray noise environment, the camera, (fig 1) consists of a 26-inch diameter, 32-inch long, lead filled housing with an opening of 12 ½-inches (fig 2).


Figure 1

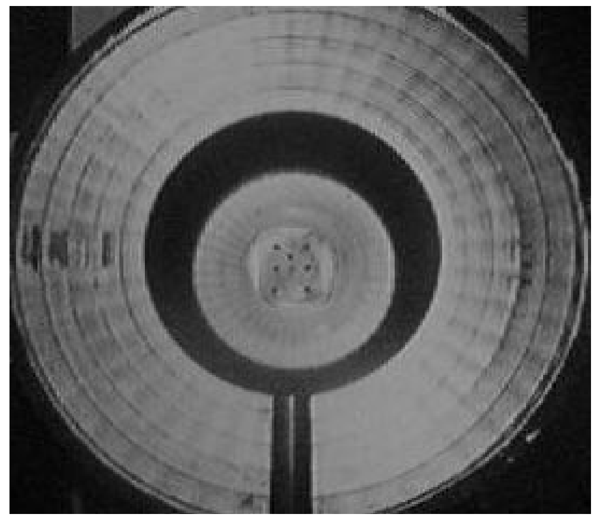


Figure 2

The reasons for the extensive lead shield is to minimize the signal from sever scattered x-ray noise. Inside the camera housing are the camera's six micro-channel plate (MCP) intensifier tubes and film holders. (fig 3)

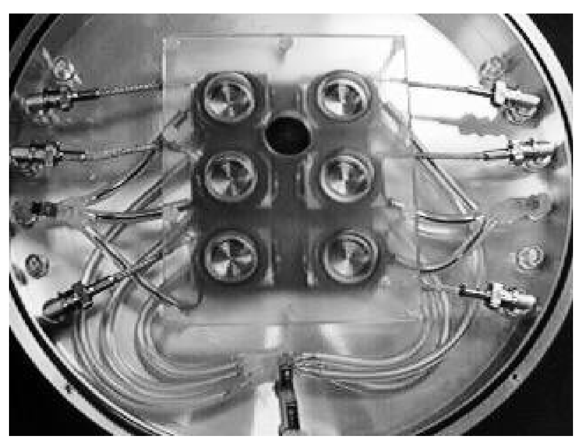


Figure 3

This housing provides a minimum of nine inches of lead shielding in front, seven inches of shielding on the sides and three inches of shielding aft, between the x-ray source and micro-channel plate MCP tubes. For imaging the x-ray spot, we are using tapered tungsten pinholes that are ~ 6 inches long with a final aperture of

.015 inch diameter. This provides us with an image resolution of ~ .3 mm with an on axis signal x-ray to scattered x-ray of over $\mathbf{1 \times 10^{6}}$ and off axis of over $\mathbf{1 \times 10^{3}}$ (fig 4).

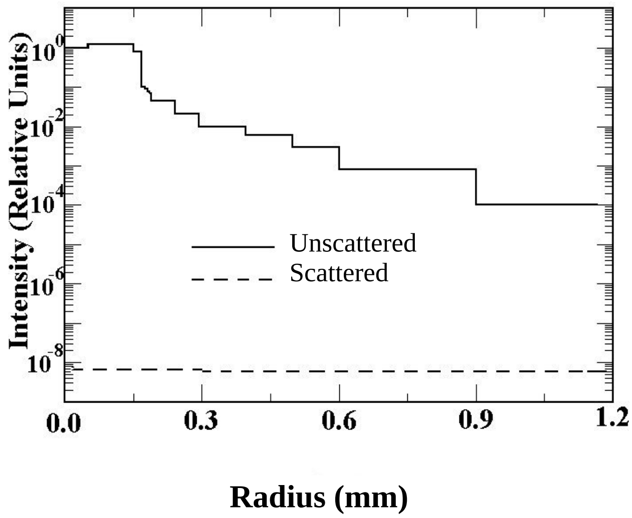



Figure 4

## 3 DRIVE ELECTRONICS

To control the timing of the individual MCP tubes in the camera, we use high-speed avalanche pulsers assembled at LLNL by Stephen Fulkerson [1]. The pulsers provide the 1-kV signal across the MCPs that in turns controls the precise gain or gating of the camera. For the experiments on ETA-II, the pulsers provide a signal for 5-ns, with each successive pulse arriving 10-ns later. This creates a 6-frame movie with an integration time or frame time of 5-ns with an inter-frame time of 5-ns (fig 5).

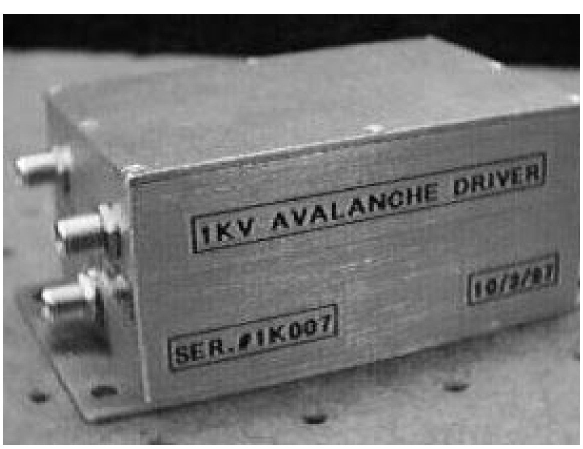



Figure 5

For monitoring the individual MCP sequencing, a sample from each pulser is summed via a resistive network. This signal is then combined to a signal from a beam current monitor which is located ~2.5 m upstream of the bremsstrahlung converter. All signals are then combined via the summing function of a Tektronix 7104 oscilloscope and recorded on film. The film is later scanned via the flatbed scanner and archived for later processing (fig 6).

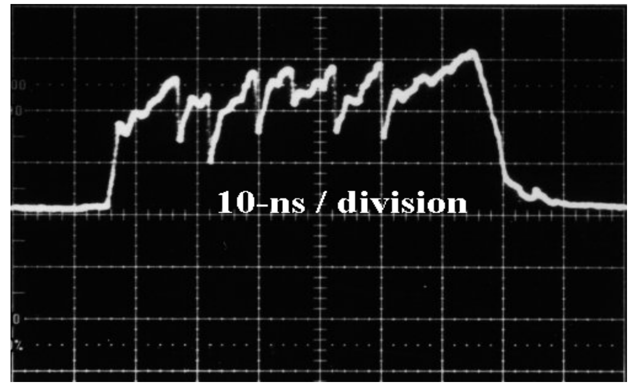


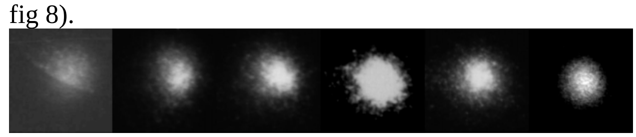

Figure 6

## 4 DATA RECORDING

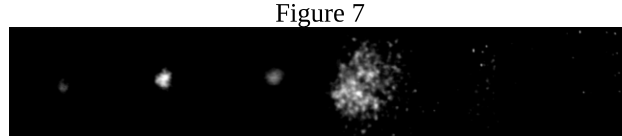
Recently, we are using Polaroid Type 52 and Type 57 file for our data recording. While this is not the optimum recording medium, this camera/film combination provides a relatively convenient recording format. After developing the film, we utilize a standard flatbed scanner with an optical resolution of 1200 dots per inch (dpi). The film is scanned as an eight-bit gray scale image at 1200 dpi. The result 22-Mb image is then stored in a Joint Photo. Expert Group (JPEG) format image file. The files are then available for image processing and data reduction

## 5 RESULTS

For the applications at ETA-II, we are presently measuring beam profiles with feature sizes from ~ .5-mm to 2.0-mm. This combination of optics, shielding, film, and digitalization, provides us with a reasonable representation of the x-ray spot behavior as a function of time. As a result of utilizing this diagnostic we have performed several critical experiments in support of DARHT and AHF programs [2,3]. An example of the raw data provided by this system, clearly demonstrates some of the unique advantages of this instrument (fig 7 & fig 8).



Example of stable beam
Figure 7



Beam blowup stimulated by laser induced plasma
Figure 8

## 6 FUTURE PLANS

Future activities include installing an array of video type cameras with a resolution in excess of 30 lp/mm. The cameras, CID Technologies Corporation's model TN 2250, create an image using a 512 element by 512 element Charge Injection Device (CID) sensor. The individual square pixels are 15-μm by 15-μm on a side. The input of the CID arrays are coupled to the output of the micro-channel plate intensifiers by means of fiber-optic tapers. This provides a convenient means of matching the 18-mm diameter MCP to the camera's ~0.3-inch x 0.3-inch CID array. With video frame-grabbers, from Imaging Technologies, containing eight-bit flash A/D converters, direct digitization and computer storage of the images is possible. This configuration should allow us to acquire, store, and pre-analyze the spatial and temporal history of the beam at a rate consistent with the accelerator operation.

## 7 ACKNOWLEDGEMENTS

*Work performed jointly for the U.S. DOE by Sandia National Laboratories, managed by Lockheed Martin Corp., under contract DE-AC04-94AL85000, Lawrence Livermore National Laboratory under contract W-7405-ENG-48 and by AlliedSignal FM&T under contract DE-ACO4-76-DP00613.

The authors would like to thank Dr. William A. Stygar from Sandia National Laboratories, Roger Van Maren, Stephen Petz from Lawrence Livermore National Laboratory, and the rest of the ETA-II team for their help and assistance. Without their help many of these experiments and results would not have been possible.

## 8 REFERENCES

[1] E. Stephen Fulkerson et al., "Driving Pockel Cells Using Avalanche Transistor Pulsers," Proceedings of 11th IEEE International Pulsed Power Conference, June 29-July 2, 1997, Baltimore, Maryland

[2] G. A. Westenskow et. al., "Experimental Investigation of Beam Optics Issues at the Bremsstrahlung Converters for Radiographic Applications," Proceedings of LINAC98, August 23-27, 1998

[3] G. J. Caporaso et al, "Analytic Model of Ion Emission from the Focus of an Intense Relativistic Electron Beam on a Target," Proceedings of LINAC98, August 23-27, 1998